System Simulation of Bunch-to-Bucket Transfer Between Synchrotrons*

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Introduction

A model of the low-level RF (LLRF) synchronization topology at SIS18 and SIS100 under Ptolemy II [1] is currently under development. This model enables to simulate the behavior of the synchronization signals during the synchronization procedure at the transfer flattop within the framework of a deterministic bunch-to-bucket transfer. The Java-based heterogeneous structure of the Ptolemy II software offers an intuitive parallelization procedure by splitting the different sub-models in concurrent threads.

Simulation of the LLRF system

The simulated LLRF system is composed of two independent and non-synchronized entities. The first entity is based on the phase advance measurement between a radio-frequency (RF) signal and a reference (REF) signal. The REF signal is derived from the periodically shared BuTiS synchronization signal $T_0 = 10\ \mu$s:

$$f_{REF} = \frac{N}{T_0} \qquad \text{with} \quad N = floor(f_{RF}T_0) \qquad (1)$$

The REF signal is generated by a DDS. A periodic reset of the DDS phase value consistent with the synchronization signal ensures that the phase advance relation between the REF signal and the synchronization signal remains constant. This REF signal can thus be duplicated to provide a fix phase measurement reference.

The phase advance measurement between the RF and the REF signal relies on a frequency transposition and a direct IQ demodulation [2]. This method benefits from a high phase measurement accuracy and a maximum error value of 0.6^o at 5.4 MHz and delivers its phase measurement asynchronously every $3.22\ \mu$s, i.e. the delay between the most recent phase advance measurement and the next slope of the synchronization signal is not constant.

The second simulated entity corresponds to an additional DDS module, which duplicates an RF signal in real time. This DDS may receive the same frequency value command as the DDS, which generates the original RF signal such, that duplicated and original RF signals have the same frequency but their phase advance relationship remains free. The measured phase advance from the first entity is used to determine the phase offset with respect to a certain time event such as a trigger derived from the synchronization signal. The duplicated DDS resets at this trigger with the calculated offset, which enables the duplicated RF signal to synchronize with the original RF signal.

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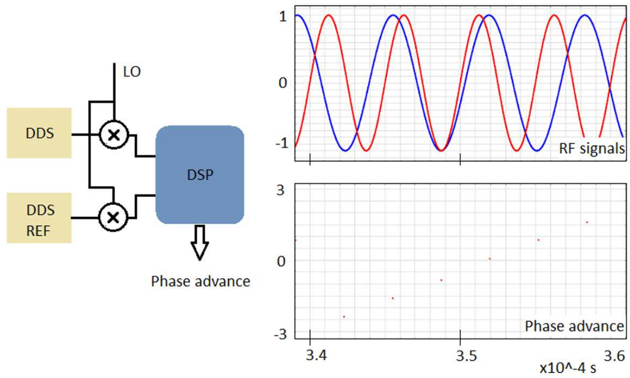

Fig 1, left: representation of the phase measurement entity.
above right: RF signals of 157 and 200 kHz.
below right: relative phase advance measurement.

A conventional synchronization loop may be used to synchronize a DDS RF signal with the locally emulated signal. In the framework of the bunch-to-bucket transfer synchronization between SIS18 and SIS100, a symmetrical implementation of this system may enable duplicating the synchronization RF signals locally, if they are required. The synchronization of such emulated systems needs a data transfer between the two supply rooms only once per acceleration cycle.

Outlook

The implementation of a hardware synchronization system on the basis of this simulation is currently under study and is expected to be implemented in the coming months. This demonstration system may enable to evaluate the reliability and the robustness of the simulation model. A simulation-based optimization for the local resynchronization procedure is foreseen.

References

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